DRAFT
TECHNICAL MEMORANDUM

TO: Washington State Department of Ecology

FROM: Area-Wide Soil Contamination Project Consultant Team

DATE: April 30, 2002

RE: SITE CATEGORIES AND REMEDIAL ACTION TECHNOLOGIES

In accordance with the scope of work and deliverable schedule for contract number C0200196, this draft technical memorandum provides the Washington State Department of Ecology (Ecology) with site categories for which remedial action alternatives to widespread, low-to-moderate soil contamination by arsenic and lead will be evaluated and the remedial action technologies to be considered in developing the remedial action alternatives (consisting of one or more of the remedial action technologies described herein).

BACKGROUND

The Departments of Ecology, Agriculture, and Health, and the Office of Community Development (the Agencies) chartered a Task Force to address issues of area-wide soil contamination by arsenic and lead in Washington State. This task force is working with two work groups and a consultant team to develop recommendations to the chartering agencies for responding to area-wide soil contamination. The information provided in this technical memorandum is one step in the process to develop a statewide strategy for responding to widespread low-to-moderate level arsenic and lead contamination in soil.

In March and April of 2002, an information survey was performed by the consultant team to identify and gather information on the status and content of past, current, and proposed area-wide soil contamination projects, public health initiatives, and cleanup activities in other states and countries, and potentially applicable remedial action technologies that might be applied to area-wide soil contamination in Washington. Information was obtained by conducting telephone interviews with personnel in research and academia, government, and with non-governmental stakeholders and by performing a literature survey. The remedial action technologies identified in this memorandum were identified based on the information obtained from this information survey and Landau Associates' prior knowledge of potentially applicable remedial action technologies.

REMEDY SELECTION PROCESS

Formulation of a statewide strategy for responding to area-wide soil contamination by arsenic and lead includes, for each site category, identification and recommendation of remedial action alternatives that remove or reduce the threats to human health and the environment that are caused by area-wide soil contamination. The following process was established for identifying recommended remedies:

- Define categories of sites at which low-to-moderate soil contamination by arsenic and/or lead may be present.
- Identify remedial action technologies that may be applicable for remediation of low-to-moderate concentrations of arsenic and/or lead in soil.
- Develop remedial action alternatives that include one or more of the identified remedial action technologies for each category of sites.
- Identify soil cleanup standards and applicable, relevant, and appropriate requirements (ARARs) for each remedial action alternative.
- Estimate costs for implementing each remedial action alternative.
- Evaluate the residual human health and environmental risks associated with each remedial action alternative.
- Evaluate the remedial action alternatives using the MTCA evaluation criteria and identify the most practicable permanent alternative for each category of sites. This recommended remedial action alternative is referred to as the recommended remedy for that site category. Other remedial action alternatives may be identified as recommended interim remedies.

This technical memorandum addresses the first two steps in this process, which are defining site categories and identifying remedial action technologies.

DEFINITION OF SITE CATEGORIES

Area-wide soil contamination with low-to-moderate arsenic and/or lead concentrations may be present at properties with various uses and physical features. For this reason, a remedial action alternative that is appropriate for some properties may not be appropriate for other properties and, therefore, evaluation of remedial action alternatives for various types of sites is necessary. Some of the possible criteria for categorizing sites include land use (e.g. residential, school, commercial, etc.); likelihood of exposure by children or other sensitive populations; development status (i.e., currently developed or undeveloped); concentrations of arsenic and lead in site soil; source of contaminants; property ownership (e.g., private or public, owner-occupied or rental property); and size of the site. Of these criteria, two have been identified as likely to have the most impact on evaluations of remedial action alternatives. These are land use, which determines likely exposure by children and other sensitive populations, and development status, which, especially for land uses other than industrial and commercial, affects the implementability of certain actions.

Based on these two criteria, three categories of properties have been identified for which different remedial action alternatives will be developed. Other categories may be more useful for other purposes, such as soil sampling design. The categories identified for use in evaluation of remedial action alternatives are: 1) industrial/commercial properties, 2) other properties prior to development, and 3) other properties after development. These categories may be described as follows:

- **Industrial/Commercial Properties:** These are sites currently used or planned to be used for industrial or commercial purposes. In general, people do not live at these sites, food is not grown at these sites, and much of the property is (or will be) covered with structures or pavement. It is assumed that, at these sites, exposure to contamination within the soil to humans, and particularly children, is limited. Remedial action alternatives implemented at these sites may differ from the remedial action alternatives employed at sites that fall in the other two categories. For example, an industrial/commercial site may be more suitable for remediation using large equipment, and there may be less risk associated with temporary hazards during construction, including noise. Because no people live at the site and human and ecological exposure is typically lower than at other types of sites, less stringent remedial options also may be appropriate for these sites.

- **Other Properties Prior to Development:** These sites include future single- or multi-family residences, parks, schools, day-care centers, etc., where exposure by adults and children is likely if no remedial action alternatives are implemented. This category also includes non-agricultural properties where future site use is not yet determined. These sites have limited infrastructure (e.g., no buildings, few or no roads, and possibly no utilities). Remedial action alternatives employed at these sites may differ from the remedial action alternatives employed at sites that fall in the "other properties after development" category. For example, an undeveloped site may be more suitable for remediation using large equipment, larger excavations, and/or larger treatment operations than a developed site. However, because people may use the site in the future as a residence, for recreation, or for growing food in a garden, remedial action alternatives that result in a more permanent remedy are expected to be preferred for these sites.

- **Other Properties After Development:** These sites include properties currently used for single- or multi-family residences, parks, schools, day-care centers, etc. These sites already are developed and contain infrastructure such as buildings, roads, utilities, paved areas, etc. Contaminated soil at these sites may be used to grow foods or may be contacted by children and adults. Remedial action alternatives that use large equipment; require large available spaces; or create temporary construction hazards, including noise, etc.; may not be feasible alternatives for these types of sites. Remedial action alternatives that result in a more permanent remedy are expected to be preferred for these sites.

IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

This section identifies and screens remedial action technologies that have been used in the site remediation industry to remediate metals-contaminated soil. The objective of the screening is to eliminate technologies that clearly are not appropriate for application to area-wide soil contamination. A broad range of remedial action technologies to be considered for screening was identified. The technologies were grouped into three categories: those that remove contaminants from site soil; those that reduce contaminant toxicity or mobility or that reduce exposure to contaminants; and those that limit the use of the property, thereby reducing exposure to contaminants. These three categories, along with a fourth no action category, and the remedial action technologies within these categories were screened for their applicability to remediation of area-wide contamination. The results of this preliminary evaluation and a brief description of each technology, by category, is provided below. Table 1 shows the remedial action technologies for each site category and indicates those that will be carried forward for further evaluation.

Remedial Action Technologies that Remove Contaminants

The remedial action technologies presented below can, by themselves or in combination with other technologies, eliminate the risk of exposure by removing contaminants from the site or reducing the contaminant concentrations through treatment to levels that do not pose unacceptable risk to human health and the environment.

Soil Removal and Offsite Treatment or Disposal

Soil removal involves excavating contaminated soil to a pre-determined depth using a backhoe, excavator, or hand implements (shovels, etc.). This action may require temporary stockpiling of the excavated soil onsite prior to placement of the soil in trucks for offsite treatment or disposal, or the excavated soil may be directly loaded into trucks. Soil transported offsite may be disposed of at an appropriately regulated landfill or treated at an offsite facility. Depending on site conditions, the excavated soil may be replaced with clean backfill.

This remedial action technology is commonly used at sites with low to high levels of soil contamination, provides a permanent remedy at a particular site, and can be implemented at most sites. Therefore, this remedial action technology has been identified as a viable remedial action technology and will be carried forward to the next step of the remedy selection process.

Soil Washing

Soil washing is a soil treatment remedial action technology applied to excavated soil. It uses an aqueous solution (which may consist only of water or may include additives such as acids, bases, surfactants, solvents, etc.) to separate heavy metals from the soil. The most basic form of soil washing is the use of water to separate fine soil particles from coarser particles; more sophisticated forms of this technology strip the contaminants from the soil particles. Soil washing is usually conducted onsite in reactor vessels or on piles of soil (e.g., heap leaching). Once the heavy metals are removed, the washed soil may be used as backfill. Soil washing often requires preparatory steps such as mechanical screening of the soil to remove various oversize materials; crushing to reduce the material to an appropriate size; and/or soaking, spraying, tumbling and/or scrubbing of the material to remove weakly bound agglomerates (i.e., silts and clays bound to sand and gravel). Soil washing also requires management of the resulting contaminated wash water and sludge. Soil washing may be applicable to one or more site categories and, therefore, has been identified as a viable remedial action technology.

Soil Flushing

Soil flushing is similar to soil washing, but in soil flushing the soil is not excavated (i.e., the soil is *in situ*). Soil flushing involves infiltrating a fluid into the contaminated soil and solubilizing the contaminants. The contaminants are then removed from the soil by extracting the fluid. Infiltration of the fluid (usually water or an aqueous solution) to the soil can be accomplished in a number of ways, including surface flooding, sprinklers, leach fields, basin infiltration systems, surface trenches, horizontal drains, or vertical drains. Soil flushing has a more established history for removal of organics than for metals, although it has been used successfully for removal of hexavalent chromium. Because use of this technology for removal of arsenic and lead has not been established, this remedial action technology is not considered to be viable and will not be further evaluated.

Electrokinetics

Electrokinetic technology involves passing a low intensity current between two electrodes imbedded in the contaminated soil. Contaminants in the form of ions and charged particles move toward one of the electrodes, depending on the charge of the ion, by electromigration (charged chemical movement) and electro-osmosis (movement of fluid). The electrokinetic treatment concentrates contaminants in solution around the electrodes. The contaminants may be removed from this solution by a variety of processes. Because the electrokinetic technology relies on the movement of contaminants in fluid, this technology is most applicable to saturated soil. Because the area-wide soil contamination is expected to be shallow and in unsaturated soil, this remedial action technology is not considered to be viable and will not be further evaluated.

Phytoremediation

Phytoremediation is the use of plants to remediate contaminated soil, sediment, and groundwater. One form of phytoremediation involves the use of plant roots to absorb, concentrate, and precipitate toxic metals from soil into the harvestable portions of roots and surface biomass (shoots, leaves, etc.). Phytoremediation is considered an innovative technology and has been investigated in the laboratory and field by government, industry, and university research groups, and has been applied at numerous sites. The technology requires site-specific studies to determine the species or varieties of plants most applicable to a given application, because plants vary greatly in their ability to uptake and metabolize specific contaminants and in their ability to grow under specific soil and climatic conditions. Phytoremediation is generally limited to shallow soil contamination; however, because the area-wide contamination is expected to be shallow, this limitation is not likely to be of concern. Because phytoremediation can be applied *in situ* to remediate shallow soil and can be used in small areas with little disturbance to the surrounding environment, this technology has been identified as a potentially viable remedial action technology.

Actions that Reduce Contaminant Mobility or Toxicity or Reduce Exposure

The remedial action technologies presented below reduce risk by reducing the contaminant mobility or toxicity or by reducing the likelihood of exposure, rather than by removing contaminants from a particular site. These technologies may be stand-alone technologies or may be combined with other technologies to reduce the risk of exposure to acceptable levels.

Solidification/Stabilization

Solidification is a physical encapsulation of the contaminants in a solid matrix. Solidification technology is typically applied by mixing contaminated soil with a physical binding agent (e.g., cement) to encapsulate the contaminated soil and limit future leaching of the contaminant from the soil. Stabilization is a chemical reaction that results in reduced contaminant mobility. Solidification/ stabilization of contaminated soil is most efficiently implemented with shallow contamination and can be used to treat either in-place soil or excavated soil that can then be returned to the excavation. For these reasons, solidification/stabilization has been identified as a viable remedial action technology. Post-remediation conditions, however, may not be conducive to residential yard use if the solidified material remains onsite.

Chemical Treatment

Chemical treatment involves the addition of chemical agents to the soil to reduce contaminant mobility and/or toxicity. Arsenic-contaminated soil may be treated by chemically oxidizing Arsenic (III) to Arsenic (V), which is less soluble, less toxic, and less mobile than Arsenic (III). Some bench-scale work has indicated that arsenic stabilization may by be achieved by precipitation and coprecipitation with Iron (III). Additionally, chemical neutralization could be used to reduce the mobility of arsenic in either highly acidic or basic soil or the mobility of lead in highly acidic soil. These types of chemical treatment are potentially applicable and, therefore, chemical treatment has been identified as a potentially viable remedial action.

Vitrification

Vitrification involves electrically heating the contaminated soil to very high temperatures, which results in the destruction of organic compounds and the immobilization of inorganic compounds through the fusion of the soil into a stable vitreous (glass) material. The vitrified material may be left in-place or removed and used as clean fill at another location. Vitrification involves high energy consumption. This high energy requirement and the associated energy costs reduce the feasibility of using this technology at sites with widespread soil contamination; therefore, vitrification was not identified as viable remedial action technology for this project and will not be further evaluated.

In situ Capping

In situ capping involves placing engineered covers or vegetative covers that reduce direct contact with contaminated soil without displacement of the soil. Engineered covers may include geosynthetic materials (fabric), asphalt or cement-concrete pavement, and soil. Vegetative covers may include grass, legume, or shrub species that provide a stand of vegetation that reduce the risk of exposure to the contaminated soil. Geosynthetic covers are typically used to reduce infiltration of surface water and would not be effective at preventing direct contact with the contaminated soil unless used in conjunction with a soil cover. Geosynthetic fabrics may be used as a marker to separate the contaminated soil from the overlying engineered cover, thereby limiting the potential for future exposure to the contaminated soil. Asphalt and concrete covers are effective at preventing direct contact with the contaminated soil, but require long-term maintenance. Soil covers are commonly used as remedial actions at contaminated sites. They are effective at reducing exposure to contaminated soil as long as they are thick enough to prevent exposure to the underlying contaminated soil during everyday activities (e.g., children or adults digging in a garden). This required thickness may pose a problem if pre-remediation surface elevations are to be maintained; in this case, some of the contaminated soil may need to be removed prior to use of a cover. Soil covers also require long-term maintenance and may require a vegetative cover to prevent erosion.

Each of the *in situ* capping technologies may be effectively used at one or all of the area-wide site categories to reduce exposure to contaminated soil; therefore, capping has been identified as a viable remedial action technology.

Ex situ Capping

Ex situ capping involves removal of some or all of the contaminated soil and consolidating it beneath a building, road, berm, or other structure/cover that would prevent or reduce the risk of direct contact to the contaminated soil. This remedial action technology is feasible at any of the area-wide soil contamination site categories and, therefore, has been identified as a viable remedial action technology.

Tilling/Soil Blending

Tilling is the mechanical mixing of contaminated surface soil with slightly deeper uncontaminated or less contaminated soil such that contaminant levels at the surface after tilling are reduced. Soil blending involves importing clean soil or other organic materials and mixing it with the contaminated soil to reduce contaminant levels. Both of these remedial action technologies may be feasible at any project site category; however, their effectiveness will depend on the depth of soil contamination and the ability to till and/or blend soil to the required depth. For example, large mechanical tillers may be used in large open areas with easy access and may be able to till to a depth of 1.5 to 2 ft; whereas, in a less accessible, smaller area, equipment access may require use of a hand rototiller that may only be able to till to a depth of about 6-inches. However, because both these methods may be feasible for reducing the risk of exposure to contaminated soil at one or more of the site categories, these methods have been identified as viable remedial action technologies.

Institutional Controls

Institutional controls are non-engineering mechanisms that provide the means by which federal, state, and local governments or private parties can prevent or limit access to or use of contaminated environmental media. Institutional controls may include local land use regulations, easements, restrictive covenants, and educational or community protective measures. Institutional controls may be applied to a site on a stand-alone basis or implemented in conjunction with other remedial action technologies as part of the overall remedial option. One or more of the institutional controls described below may be applied to one or all of the site categories and may be effective in reducing the risk of exposure to contaminated soil. Therefore, institutional controls have been identified as a viable remedial action technology.

Land Use Regulations

Local land use regulations may include subdivision ordinances or zoning regulations implemented by the local government to limit access and property uses for the purpose of protecting human health and the environment.

Easements

Easements may be created by a grant from a property owner to another person or government entity prohibiting the property owner from conducting certain activities to protect human health and the environment.

Restrictive Covenants

Restrictive covenants are written restrictions or requirements placed on the title to real property that pass with the property and bind both current and future owners of the property to prohibit activities that may have the potential to cause a human health or environmental threat.

Educational or Community Protective Measures

Educational or community protective measures may include informing the community or property owners and occupants of the risks associated with direct contact to soil contaminated with low-to-moderate levels of arsenic and/or lead and informing the community or property owners and occupants of measures that can be taken to reduce the risk of exposure (i.e., hand washing, washing vegetables grown in potentially contaminated soil, etc).

No Action

No action would involve performing no remedial action technologies at a site. A no action alternative may be viable if lead or arsenic concentrations at a site are determined not to pose unacceptable risks to human health and the environment. This alternative may also be appropriate for a site if implementation of remedial action alternatives would create a greater risk, or if the cost of remediation is excessive when compared to risk reduction.

SUMMARY

In summary, three categories of sites were identified for which recommended remedies will be identified: industrial/commercial, other properties prior to development, and other properties after development. Remedial action technologies that were retained as viable include: solidification/stabilization, chemical treatment, soil removal with offsite disposal or treatment, soil washing, phytoremediation, *in situ* capping, *ex situ* capping, tilling/soil blending, institutional controls, and no action. Potential remedial action alternatives, including one or more of these technologies, will be identified for each site category as the next step in the remedy evaluation process. The remedial action alternatives will be further evaluated to identify appropriate remedies for each site category.

TABLE 1
SITE CATEGORIES AND
REMEDIAL ACTION TECHNOLOGIES

	SITE CATEGORIES		
REMEDIAL ACTION CATEGORIES AND TECHNOLOGIES	INDUSTRIAL/ COMMERCIAL	OTHER PROPERTIES PRIOR TO DEVELOPMENT	OTHER PROPERTIES AFTER DEVELOPMENT
TECHNOLOGIES TO REMOVE CONTAMINANTS			
Excavation & Offsite Treatment or Disposal	X	X	X
Soil Washing	X	X	X
Soil Flushing			
Electrokinetics			
Phytoremediation	X	X	X
TECHNOLOGIES TO REDUCE CONTAMINANT MOBILITY OR TOXICITY OR TO REDUCE EXPOSURE			
Solidification/Stabilization	X	X	X
Chemical Treatment	X	X	X
Vitrification			
In situ Capping	X	X	X
Ex situ Capping	X	X	X
Tilling/Soil Blending	X	X	X
INSTITUTIONAL CONTROLS			
Land Use Regulations	X	X	X
Easements	X	X	X
Restrictive Covenants	X	X	X
Education/Community Protection Measures	X	X	X
NO ACTION ALTERNATIVE	X	X	X

X = Indicates technology will be carried forward for further evaluation.